HYBRID FASTENER APPARATUS AND METHOD FOR FASTENING

BACKGROUND OF THE INVENTION

1) Field of the Invention

The present invention relates to composite fasteners for fastening structural members, i.e., fasteners formed at least partially of a composite material, such as hybrid fasteners formed of a combination of composite and metallic materials, and/or blind composite fasteners.

2) Description of Related Art

High-strength composite materials are increasingly being used in the manufacture of various types of structural members due to improved physical properties and economic availability of the materials. Along with this increased use, the composite materials are more commonly being used in conjunction with metallic components in situations that require structural integrity and fatigue resistance. For example, structural members for aerospace applications that are formed of high-strength composites such as carbon/epoxy, polyaramid/epoxy, or glass/epoxy composites are mechanically fastened using high-strength metallic aerospace fasteners. Such fasteners are typically formed of metallic materials such as titanium and stainless steels that are different from the composite materials of the structural members. Therefore, the fasteners often have physical characteristics that are dissimilar to or incompatible with the composite materials of the structural members being fastened. In some cases, the use of dissimilar materials can result in delamination of the composite structural members caused by the fastener under installation and operational loads, inadequate sealing surrounding the fastener and therefore leakage of fluids through the joined components, inadequate electrical continuity between the composite components and arcing across the gaps surrounding the fasteners, galvanic corrosion between the fasteners and components at the composite joint, increased weight of the joined components, and/or nonuniform coefficients of thermal expansion between the fastener material and the surrounding composite material.

Still, metallic fasteners can also be provided with an organic corrosion-inhibiting coating. The metallic fasteners provide adequate strength, and the organic coating improves the compatibility of the metallic fastener with the joined composite materials. However, the dissimilarity of the metallic fastener material properties and the composite materials joined in the assembly can still result in delamination, inadequate electrical continuity, galvanic corrosion, and nonuniform expansion between the materials.

Some fasteners formed of composite materials such as PEEK™ can be subject to the same problems, as noted above. Further, current fasteners formed of composite materials are generally not adapted for blind installation. For example, the installation of two-piece composite fasteners such as threaded pins or bolts generally requires the threaded pin or bolt to be inserted from a first side of the structural members being joined with access for installation of a nut at the opposite side. Similarly, one-piece composite rivets generally must be inserted from a first side of the structure to be assembled and then upset at the opposite side. Such fasteners, either one-piece or two-piece, generally cannot be used for fastening applications in which one side of the structural members is inaccessible. Further, even if both sides are accessible, access to both sides of the fastener can require additional tooling and/or processing steps.

Thus, a continued need exists for improved fasteners that can be used with either composite or metallic and composite structural members for aerospace and non-aerospace applications. Preferably, the fasteners should be adaptable for fastening multiple composite structural members or a combination of composite or metallic structural members while reducing or eliminating the occurrence of problems relating to delamination, electrical continuity, galvanic corrosion, and nonuniform expansion that are associated with metallic fasteners and conventional composite fasteners. Further, the fasteners should be adaptable for blind installation, that is, an installation having no or limited access from one side of the structure to be assembled.

SUMMARY OF THE INVENTION

The present invention provides fasteners and methods for fastening non-metallic and metallic structural members. The fasteners can be formed at least partially of composite materials, e.g., as a hybrid fastener formed partially of a composite material and partially of a metallic material. The fasteners can be compatible with the materials of the structural members to be fastened, such as where

one or more of the structural members is formed of a composite material. Thus, the composite material of the fastener can reduce the galvanic corrosion that might otherwise result if a conventional metallic fastener were used. Further, the composite material of the fastener can have characteristics similar to or the same as those of the structural members, thereby improving the electrical continuity of the structural members, reducing the likelihood of delamination, and reducing differentials in thermal expansion coefficients that might otherwise occur. In some cases, the fastener can be installed blindly, i.e., the fastener can be disposed and deformed from a single side of the structural members without requiring access to the opposite side of the structural members.

According to one embodiment, the present invention provides a composite-metallic hybrid fastener for installation in an aperture through structural members for fastening the structural members. The hybrid fastener includes a composite sleeve and a metallic stem. For example, the composite sleeve can be formed of a composite material having carbon or fiberglass reinforcing fibers disposed in a polymeric resin matrix, and the stem can be formed of titanium or titanium-alloy material. The sleeve extends from a first side to a second side and defines a head at a second side and an aperture through the sleeve. A cross-sectional dimension of the head is at least as great as a cross-sectional dimension of the aperture of the structural members. The stem includes a shank with a deformable head at a first end thereof, such as an annular portion that extends around the shank. The shank can be disposed through the structural members and the sleeve, and the head of the stem is capable of being compressed toward the sleeve and thereby deformed to a cross-sectional dimension that is at least as great as the cross-sectional dimension of the aperture through the structural members. For example, the shank and the aperture through the sleeve can define corresponding or mating threads so that the shank can be screwed into the sleeve to deform the head of the stem against the sleeve. Thus, the structural members can be fastened between the head of the sleeve and the deformable end of the stem.

The present invention also provides a blind fastener that is formed at least partially of a composite material. The fastener has a shank with first and second heads at opposite ends thereof. The second head has a cross-sectional dimension that is at least as great as a cross-sectional dimension of the aperture. The first head has a cross-sectional dimension less than the cross-sectional dimension of the aperture so

that the first head can be inserted through the aperture of the structural members from the first side to the second side of the structural members. The first head is deformable to a cross-sectional dimension greater than the cross-sectional dimension of the aperture to fasten the structural members between the two heads. The first head can be deformed by a blind adjustment or functioning of the second head and the shank at the first side of the structural members.

In any case, the fastener can also include a plastic insert between the stem and the sleeve that forms a seal therebetween when the head of the stem is deformed. In addition, or alternative, one or both of the stem and the sleeve can be pre-coated with a curable organic coating. Further, the stem can define a breakneck feature such as a circumferential groove that is configured to fail in tension after the head of the stem has been fully deformed and exerts a pre-established minimal tensile load.

According to one method of the present invention, a fastener is used to fasten and assemble structural members. The fastener defines a shank with heads at opposite ends thereof, and the fastener is formed at least partially of a composite material. For example, the second head can be formed of a composite material and the shank can be formed of metal. The shank is disposed in an aperture so that the second head is disposed at a first side of the structural members and the first head is disposed at a second side of the structural members opposite the first side. The second head has a cross-sectional dimension greater than a cross-sectional dimension of the aperture, and the first head is deformed to a cross-sectional dimension greater than the cross-sectional dimension of the aperture, thereby fastening the structural members between the two heads. The fastener can be blindly disposed and deformed. That is, the fastener can be disposed from the first side of the structural members, and the first head can also be deformed or upset from the first side of the structural members.

According to one aspect of the invention, a plastic insert or metallic lock or locking ring of the locking feature is disposed between the stem and the sleeve to form a seal or locking feature between the two components. Additionally or alternatively, the fastener can be pre-coated with a curable organic coating. Further, the shank can be broken so that a portion of the shank can be removed from the fastener after the first head is deformed.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other advantages and features of the invention, and the manner in which the same are accomplished, will become more readily apparent upon consideration of the following detailed description of the invention taken in conjunction with the accompanying drawings, which illustrate preferred and exemplary embodiments, and which are not necessarily drawn to scale, wherein:

Figure 1 is an exploded perspective view illustrating a composite-metallic hybrid fastener according to one embodiment of the present invention;

Figure 2 is a section view illustrating the composite-metallic hybrid fastener of Figure 1 disposed through two structural members;

Figure 3 is a section view illustrating the composite-metallic hybrid fastener of Figure 1 after the first head of the fastener has been deformed to fasten the structural members together;

Figure 4 is a perspective view illustrating the second head details of a composite-metallic hybrid fastener according to another embodiment of the present invention;

Figure 5 is a section view illustrating the composite-metallic hybrid fastener of Figure 4 disposed through two structural members; and

Figure 6 is a section view illustrating the composite-metallic hybrid fastener of Figure 4 after the first head of the fastener has been deformed and the locking ring has been installed.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring now to the drawings, and in particular to Figure 1, there is illustrated a composite-metallic hybrid fastener **10**, which can be used for fastening structural members. In particular, as shown in Figures 2 and 3, the fastener **10** can be installed in an aperture **54** that extends between first and second sides **56, 58** of the structural

members **50**, **52** to thereby fasten the structural members **50**, **52**. The fastener **10** is compatible with various types of structural members. For example, the fastener **10** can be used to fasten multiple composite structural members, or a combination of at least one composite structural member and at least one metallic structural member. That is, each of the structural members **50**, **52** can be a metallic member or a non-metallic member such as a composite member. It is also appreciated that any number of structural members can be fastened with the fastener **10**. For example, two or more structural members **50**, **52** can be positioned in an overlapping configuration, as shown in Figure 2, and the fastener **10** can be disposed therethrough. In some cases, the fastener **10** can fasten a single structural member, e.g., a structural member that is folded, curved, or otherwise bent so that two or more portions of the member are positioned in an overlapping configuration. As such, reference to the fastening of structural members shall include both the fastening of two or more distinct structural members, and the fastening of two or more portions of a single structural member. In any case, the structural members **50**, **52** can be used in various applications including, but not limited to, aerospace vehicles and structures, other vehicles such as automobiles or marine vehicles, building structures, and the like.

The fastener **10** illustrated in Figure 1 is an exemplary fastener according to the present invention, but the fastener **10** can alternatively be configured as any of a number of other fastening devices. As shown in Figure 1, the fastener **10** includes a sleeve **12** and a stem **30**. The stem **30** has a shank portion **32** that extends between first and second ends **34**, **36**. The first end **34** defines a head **38** and the second end **36** is configured to be inserted through an aperture **16** defined by the sleeve **12**. The sleeve **12** can engage the shank **32**, e.g., by virtue of corresponding threads **14**, **40** provided on the inner surface of the aperture **16** extending through the sleeve **12** and on the outer surface of the shank **32** of the stem **30**, respectively. More particularly, the stem **30** can be engaged to the sleeve **12** by inserting the second end **36** of the shank **32** into the aperture **16** and screwing the shank **32** therethrough until the head **38** contacts the sleeve **12**.

The fastener **10** is formed partially of a metallic material and partially of a non-metallic material such as a composite material. More particularly, the stem **30** of the fastener **10** can be formed of a metallic material such as titanium, aluminum, steel, or alloys thereof. The sleeve **12** of the fastener **10** can be formed of a composite material.

The term "composite material," generally refers to a fiber-reinforced material disposed in, or impregnated with, a resin matrix material. The resin matrix material can be any of a number of thermoplastic or thermoset polymeric resins. Exemplary thermosetting resins include allyls, alkyd polyesters, bismaleimides (BMI), epoxies, phenolic resins, polyesters, polyurethanes (PUR), polyurea-formaldehyde, cyanate ester, and vinyl ester resin. Exemplary thermoplastic resins include liquid-crystal polymers (LCP); fluoroplastics, including polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), perfluoroalkoxy resin (PFA), polychlorotrifluoroethylene (PCTFE), and polytetrafluoroethylene-perfluoromethylvinylether (MFA); ketone-based resins, including polyetheretherketone (PEEK™, a trademark of Victrex PLC Corporation, Thorntons Cleveleys Lancashire, UK); polyamides such as nylon-6/6, 30% glass fiber; polyethersulfones (PES); polyamideimides (PAIS), polyethylenes (PE); polyester thermoplastics, including polybutylene terephthalate (PBT), polyethylene terephthalate (PET), and poly(phenylene terephthalates); polysulfones (PSU); poly(phenylene sulfides) (PPS).

PEEK™ polymer is relatively easy to process and has good chemical resistance, abrasion resistance, high-temperature resistance, hydrolysis resistance, flame resistance with low smoke and toxic gases, excellent electrical properties, and excellent resistance to gamma rays. As with many of the composite polymers, PEEK™ polymer may be mixed with other resins or fillers, such as glass, aramid, or carbon fibers, through known methods, such as via melt compounding.

The reinforcement material, which can be provided as fibrous pieces or strands, tows, woven or nonwoven mats, and the like, can be any of a variety of fibrous materials such as fiberglass, metal, minerals, conductive or nonconductive graphite or carbon, nylon, aramids such as Kevlar®, a registered trademark of E. I. du Pont de Nemours and Company, and the like.

The resin matrix and reinforcement material can be selected according to the desired mechanical, physical, chemical, thermal, and electrical requirements of any particular application. For example, some fiber additives provide additional strength, while others provide enhanced electromagnetic and radio frequency shielding. Exemplary composite combinations include carbon/epoxy, Kevlar®/epoxy, and fiberglass/epoxy. Depending on the polymer of the matrix, different amounts of fiber reinforcement provide improved tensile strength, dimensional stability, cut-through resistance, flex modulus, and resistance to stress cracking, creep, warpage, and heat

deflection or expansion. By way of example, 20% to 30% glass-filled PFA and PEEK™ fluoropolymers have been found to have superior mechanical properties resulting from fiber reinforcement with the outstanding thermal, chemical, and electrical properties of these polymeric resins. Glass, carbon, or titanate fibers generally can be compounded into fluoropolymers at levels up to about 30%. In addition, additives can be used to increase flame retardency, to improve lubricity or, in the case of pigments, simply to change the color of the final product. The operations for forming components of composite materials generally include disposing the reinforcement material in the matrix material and then curing the matrix material. Various particular forming techniques can be used to make components such as the composite sleeve **12** of the fastener **10**. These techniques are generally known in the art.

The sleeve **12** is configured to be installed in the aperture **54** defined by the structural members **50, 52**. In particular, the sleeve **12** extends between first and second sides **18, 20**. The first side **18** of the sleeve **12** can be smaller than the aperture **54** through the structural members **50, 52** so that the sleeve **12** can be at least partially inserted into the aperture **54**. However, the second side **20** of the sleeve **12** defines a head portion **22** with a cross-sectional dimension that is similar to or greater than the corresponding cross-sectional dimension of the aperture **54**. For example, the head **22** and the aperture **54** are typically circular, with the head **22** having a diameter that is similar to or greater than the diameter of the aperture **54**. Thus, the head **22** is secured against the first side **56** of the structural member **50**. As shown in Figure 2, each of the head **22** of the sleeve **12** and the aperture **54** through the structural members **56, 58** can have a correspondingly tapered or flared shape so that the second side **20** of the sleeve **12** is substantially flush with the first side **56** of the structural member **50** when the sleeve **12** is disposed in the aperture **54**. Thus, as shown in Figure 2, the sleeve **12** can be disposed in the aperture **54** so that the sleeve **12** extends from the first side **56** of the structural member **50** through the aperture **54** to extend outwardly from the second side **58** of the structural member **52**. It is appreciated, however, that the sleeve **12** in other embodiments can be otherwise configured.

The head **38** of the stem **30** also has a cross-sectional dimension that is smaller than the corresponding cross-sectional dimension of the aperture **54** through the structural members **50, 52**. For example, both the head **38** of the stem **30** and the first side **18** of the sleeve **12** can have a diameter that is about equal to or less than the

diameter of the aperture **54** through the structural members **50, 52**. Thus, the stem **30** can be threaded into the sleeve **12**, as shown in Figure 2, and the fastener **10** can be inserted through the aperture **54** of the structural members **50, 52** so that the head **38** of the stem **30** is disposed at the second side **58** of the structural member **52** and the head **22** of the sleeve **12** is disposed at the first side **56** of the structural member **50**.

The shank **32** of the stem **30** can define connection features opposite the head **38**, such as flat grip surfaces **42** on opposite sides of the shank **32**, which can be engaged by a conventional rotatable tool **60**. For example, the tool **60** shown in Figure 2 includes a gripping member **62** with opposed surfaces **64** that engage the grip surfaces **42** of the shank **32**. The tool **60** also has an outer tubular portion **66** that can be pressed against the sleeve **12** to prevent the sleeve **12** from moving in the aperture **54**. For example, the outer tubular portion **66** can mate or engage with slots **17** or torque recess features on the second side **20** of the sleeve **12** to prevent the sleeve **12** from rotating as torque is applied during the installation of the fastener **10**. The gripping member **62** is rotatable within the outer tubular portion **66**. Thus, the tool **60** can be engaged to the fastener **10** by inserting the shank **32** of the stem **30** between the opposed surfaces **64** of the gripping member **62** and advancing the tool **60** toward the fastener **10** until the outer tubular portion **66** contacts the second side **20** of the sleeve **12**.

The fastener **10** is then installed by rotating the stem **30** relative to the sleeve **12** so that the head **38** of the stem **30** is deformed, or upset, against the sleeve **12** and/or the second side **58** of the structural member **50**. For example, as shown in Figure 2, the first side **18** of the sleeve **12** can extend from the aperture **54** through the structural members **50, 52**, and the first side **18** can define a tapered portion. As the shank **32** is rotated relative to the sleeve **12**, the stem **30** is adjusted into the sleeve **12** and toward the tool **60**. The head **38** of the stem **30** can define various deformable configurations, i.e., such that the head **38** is capable of being upset. For example, as shown in Figure 2, the head **38** defines an annular portion that extends circumferentially around the shank **32**. As the stem **30** is tightened against the sleeve **12**, the head **38** is received onto the tapered first side **18** of the sleeve **12** and the head **38** is deformed, or upset, as shown in Figure 3. Thus, the structural members **50, 52** are compressed between the heads **22, 38** of the sleeve **12** and the stem **30** and fastened therebetween.

As shown in Figures 2 and 3, a plastic insert **44** can be provided in a gap **46** between the annular portion of the head **38** of the stem **30** and the shank **32**. The insert **44** can be deformed between the stem **30** and the sleeve **12** during deformation of the head **38** of the stem **30**. As shown in Figure 3, the insert **44** can form a seal between the stem **30** and the sleeve **12** such that the fastener **10** seals the aperture **54**. The fastener **10** can also be formed without the plastic insert **44**, and the fastener **10** can seal the aperture **54** even without the insert **44**. In either case, the fastener **10** can be configured to seal the aperture **54** and prevent liquid or gas from flowing through the aperture **54** of the structural members **50, 52** or into the aperture **54** to contact the various inner layers of the structural members **50, 52**. Such sealing can be achieved even without the use of a wet polysulfide sealant material on the surfaces of the composite structural members **50, 52** being fastened, as is used in one conventional riveting operation.

The shank **32** can also define a breakneck feature **48**, e.g., a circumferential groove around the shank **32** that defines a weakened portion of the shank **32**. The breakneck feature **48** can be designed to fail under a predetermined minimum tensile load so that when the head **38** of the stem **30** is sufficiently deformed, the required torque for further rotation of the stem **30** is sufficient to break the shank **32** at the breakneck feature **48**. Thus, the portion **32a** of the shank **32** opposite the head **38** from the breakneck feature **48** can be removed from the fastener **10** during installation of the fastener **10**, as shown in Figure 3.

As described in the foregoing exemplary operation of installation, the fastener **10** is adapted for a blind installation. That is, the fastener **10** can be disposed in the aperture **54** and deformed to fasten the structural members **50, 52** from a single side of the structural members **50, 52**. In particular, the stem **30** can be screwed into the sleeve **12**, as shown in Figure 2, and the fastener **10** can then be inserted into the aperture **54** of the structural members **50, 52** from the first side **56** of the structural members **50, 52**. Thereafter, the tool **60** can be used to deform the head **38** of the stem **30** from the first side **56** of the structural members **50, 52**. Thus, the head **38** of the stem **30** is deformed and the structural members **50, 52** are fastened without requiring access to the second side **58** of the structural members **50, 52**. In this regard, the fastener **10** can be used to fasten structural members **50, 52** even when it is impractical or impossible to access both sides of the structural members. Further, even if both sides of the structural members are accessible, such a blind installation

allows the fastener **10** to be installed without providing tooling to both sides, thereby potentially simplifying the tooling for installation and the installation process.

According to one embodiment of the present invention, one or more of the components of the fastener **10** can be pre-coated. "Pre-coated" or "pre-coating" of a fastener generally refers to a process by which a coating is applied to all or part of the fastener during its fabrication before the fastener is ready for use. For example, the sleeve **12** and/or the stem **30** can be pre-coated with a curable organic coating by spraying, dipping, brushing, or otherwise applying a solution of the coating material. If the solution includes a carrier liquid, the carrier liquid can be evaporated, leaving a layer of the coating that can be cured. The coating material can be provided to protect the material of the sleeve **12** and/or the stem **30** from corrosion, such as conventional electrolytic corrosion, galvanic corrosion, or stress corrosion. Pre-coating of composite fasteners with cured organic coatings is further described in U.S. Application No. _____________, entitled "Method For Preparing Pre-Coated, Composite Components and Components Prepared Thereby," filed March 3, 2004 and assigned to the assignee of the present application, the entirety of which is incorporated herein by reference. Pre-coating of metallic fastener components with curable organic coatings is further described in U.S. Patent No. 6,499,926, entitled "Fastener Apparatus and Method of Fastening Non-Metallic Structures," which issued December 31, 2002 and is assigned to the assignee of the present application, the entirety of which is also incorporated herein by reference.

It is appreciated that the blind hybrid composite fastener **10** of the present invention, which includes the combination of non-metallic (e.g., composite) and metallic components, can be lighter in weight than a similar fastener formed entirely of metallic materials. That is, the non-metallic, composite sleeve **12** of the fastener **10** shown in the figures can be lighter than a similar sleeve formed of various types of metal by virtue of the reduced material density. For example, according to one embodiment of the blind hybrid composite fastener **10** of the present invention, the combined weight of 1000 of the fasteners **10** is between about 2.1 and 2.3 lbs. In comparison, 1000 conventional metallic fasteners typically weigh between about 4 and 7 lbs. In addition, in cases where the fastener **10** is used to secure at least one structural member **50, 52** that is formed of a composite material, the sleeve **12** can be formed of a composite material that is the same as, similar to, or otherwise compatible with the composite material of the composite structural member to be joined, thereby

providing enhanced performance, such as improved corrosion protection, compatible coefficients of thermal expansion, reduced matrix damage, reduced electrical arcing, and the like to the joined structural members and/or the fastener **10** as compared to composite structural members that are fastened with metallic fasteners. In addition or alternative to the compatibility between the material of the composite sleeve **12** and the structural members **50, 52**, the composite sleeve **12** can be pre-coated so that the outer surfaces of the sleeve **12** are similar to or provide enhanced compatibility with the structural members **50, 52** and/or the fastener's metallic stem **30**.

The use of composite materials in the fastener **10** can also improve a number of other properties or characteristics of the fasteners **10**, as desired for particular applications. For example, the blind composite or hybrid fasteners **10** of the present invention can be used for aircraft and can result in reduced radar visibility of the aircraft. The fasteners **10** can also provide continuous electrical continuity to the composite structural members **50, 52** and thereby reduce the risk of arcing between the fasteners **10** and the structural members **50, 52** if the aircraft is struck by lightning or otherwise subjected to large electrical potentials. Further, the sleeve **12** and, hence, the fastener **10**, can exhibit bearing stress and strain characteristics that are similar to the composite structural members **50, 52**, thereby reducing the likelihood of damage to the matrix of the composite structural members **50, 52** if the structural members **50, 52** are loaded or stressed against the fastener **10**.

It is also appreciated that the members of the fastener **10** can alternatively be structured in various other configurations. For example, Figures 4-6 illustrate a fastener **10** according to another embodiment of the present invention. The aperture **54** through the structural members **50, 52** defines a generally uniform diameter throughout, and the fastener **10** is structured to be disposed in the aperture **54** with a second side **20a** of the sleeve **12** having a rounded configuration and protruding from the surface **56** of the structural member **50**. Further, the shank **32** of the stem **30** is threaded only partially, i.e., the shank **32** defines an unthreaded portion **33** extending from the head **38** of the stem **30** partially to the breakneck feature **48**. As described above, the sleeve **12** can define slots **17** or torque recess features (Figure 4) for mating or engaging with the outer portion **66** of the tool **60** during installation so that the tool **60** can be used to prevent the sleeve **12** from rotating as torque is applied during the installation of the fastener **10**. Thus, the shank **32** can be rotated relative to the sleeve

12, as described above in connection with Figures 2 and 3, during the installation process in order to deform the head **38**.

As shown in Figures 5 and 6, the fastener **10** can also include a locking ring **70** for engaging the stem **30** and the sleeve **12**, i.e., by securing the stem **30** to the sleeve **12** and/or forming a seal therebetween. The locking ring **70** can be any one of various types or designs of conventional members. For example, the locking ring **70** can be an annular member that is disposed on the stem **30** at the second side **20a** of the sleeve **12** and pressed into a gap **72** between the shank **32** and the aperture **16** of the sleeve **12** by the tool **60** during installation. Thus, the locking ring **70** can secure the stem **30** to the sleeve **12** to prevent the two components **12, 30** from separating after installation. Additionally or alternatively, the locking ring **70** can seal the gap **72** to prevent the flow of fluid through the aperture **16**. The locking ring **70** is typically formed of a metallic material such as stainless steel or titanium, and the locking ring **70** can be pre-coated as described above. It is appreciated that the locking ring **70** can be used in conjunction with other embodiments of the fastener **10**, such as the embodiment illustrated in Figures 1-3.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.